ENGINEERING THE UNDERWORLD

Harnessing the potential power of the ecological engine of the earth

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Re-imagining agriculture: engineering as the strategic enabler

Cranfield, 21 May 2014

A LITTLE LOCAL DIFFICULTY....


PROCEEDINGS OF THE ROYAL SOCIETY B

rspb.royalsocietypublishing.org

Perspective

Cite this article: Ehrlich PR, Ehrlich AH. 2013 Can a collapse of global civilization be avoided? Proc R Soc B 280: 20122845. http://dx.doi.org/10.1098/rspb.2012.2845

Received: 28 November 2012
Accepted: 7 December 2012

Can a collapse of global civilization be avoided?

Paul R. Ehrlich† and Anne H. Ehrlich

Department of Biology, Stanford University, Stanford, CA 94305, USA

Environmental problems have contributed to numerous collapses of civilizations in the past. Now, for the first time, a global collapse appears likely. Overpopulation, overconsumption by the rich and poor choices of technologies are major drivers; dramatic cultural change provides the main hope of averting calamity.

1. Introduction

Virtually every past civilization has eventually undergone collapse, a loss of socio-political-economic complexity usually accompanied by a dramatic decline in population size [1]. Some, such as those of Egypt and China, have recovered from collapses at various stages; others, such as that of Easter Island or the Classic Maya, were apparently permanent [1,2]. All those previous collapses were local or regional; elsewhere, other societies and civilizations persisted unaffected. Sometimes, as in the Tigris and Euphrates valleys, new civiliza-

PLANETARY MATTERS

Earth…



earth…



OUTLINE



- Nature and properties of soils
- Implications arising
- Re-imagining the role of soils in agriculture
  - Imperatives
  - Potentials
  - The far future
- Seedline

WHAT IS SOIL ?





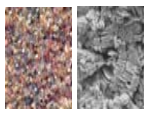
A RESOURCE !

A STRUCTURED, POROUS MEDIUM

AN ADAPTIVE, DYNAMIC SYSTEM

A HABITAT

SOIL CONSTITUENTS



Minerals



Gases



Organic matter



Water

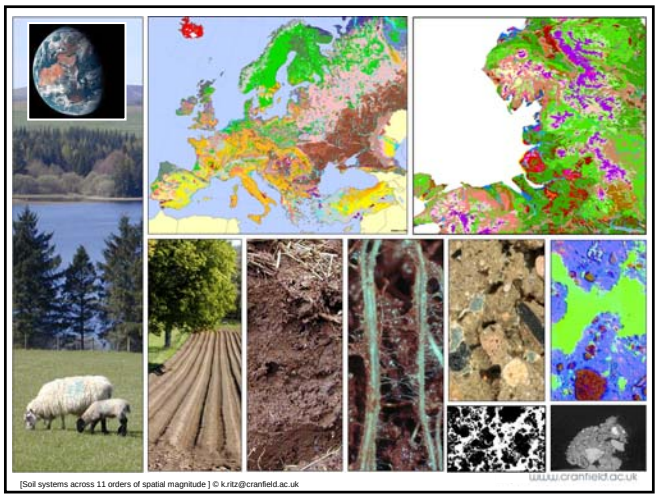


Organisms

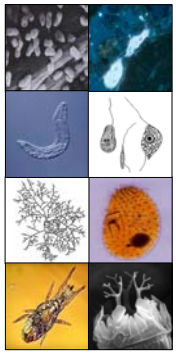


Solutes & colloids

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SOIL BIOTA



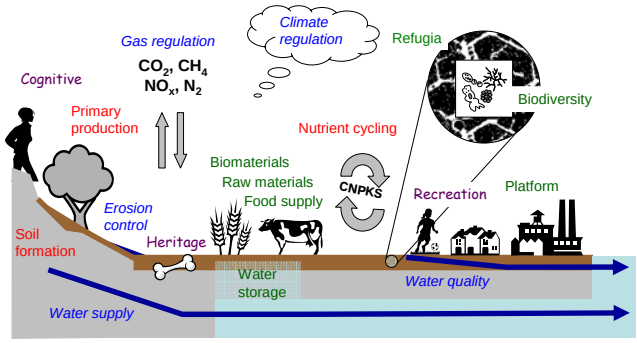
"BIOLOGICAL ENGINE OF THE EARTH"

Soil functions

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SOIL-BASED ECOSYSTEM GOODS AND SERVICES

Supporting *Regulating*
Provisioning *Cultural*



Haygarth & Ritz 2009, Land Use Policy 26 S187-197

SOIL BIOTA



"BIOLOGICAL ENGINE OF THE EARTH"

RESILIENCE

ADAPTIVE

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WHY IS BIODIVERSITY IMPORTANT ?

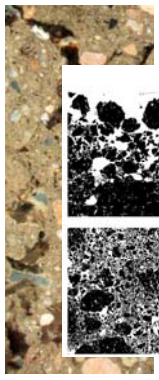




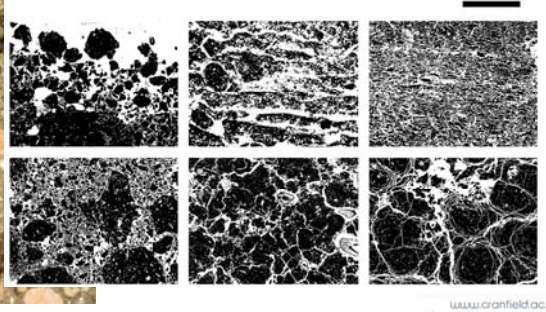
- "Biological toolbox"
  - more diverse = more tools
- For now…
  - functions needed at present
- For the future…
  - potential for future adaptation
  - resilience to a changing environment

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WHY IS SOIL STRUCTURE IMPORTANT ?

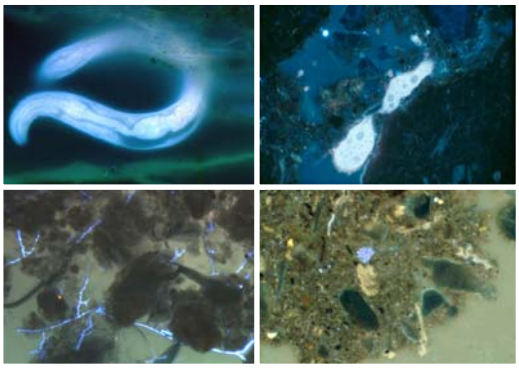


- **Fundamental** to soil functioning !



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LIFE….



SOIL ARCHITECTURE





- Soil is a living system, founded on an appropriate spatial configuration
- Appropriate community structures living within such an inner space lead to an effective functioning of the system

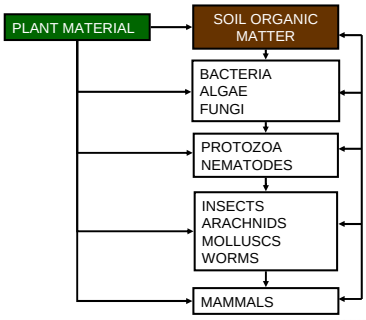
THE WORKING SOIL ENGINE

CARBON

THE FUEL OF THE SOIL ENGINE



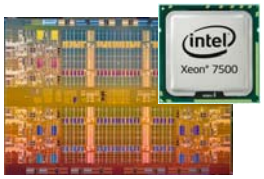
FOOD WEBS:



COMPLEX SYSTEM ENGINEERING

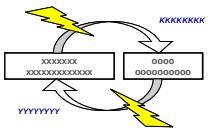


- 5 g grassland soil
  - 10^9 organisms
- Nanoscale structure
- Surface area 7000 m^2
- Indeterminate structure
- Indeterminate system



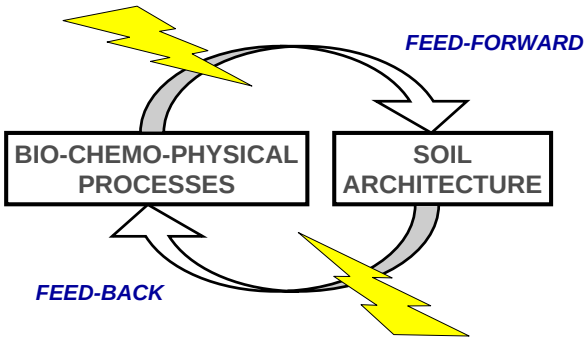
- Intel Xeon 750 processor
  - 10^9 transistors
- Nanoscale structure
- Surface area 700 mm^2
- Totally determinate structure
- Partially indeterminate system

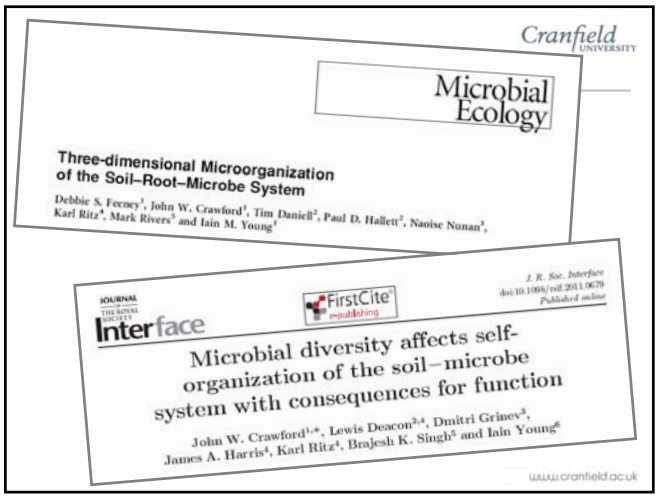
SELF-ORGANISATION IN SOILS ?



- Biological
  - community assembly rules...
- Structural genesis and dynamics
  - physically mediated
  - biologically mediated

SELF-ORGANISATION IN SOILS ?





SOILS AND AGRICULTURE



NOT IMAGINING: IMPERATIVES

- SOIL MAINTENANCE
  - inputs to the system
    - energy (C)
    - nutrients
  - biodiversity
  - architecture



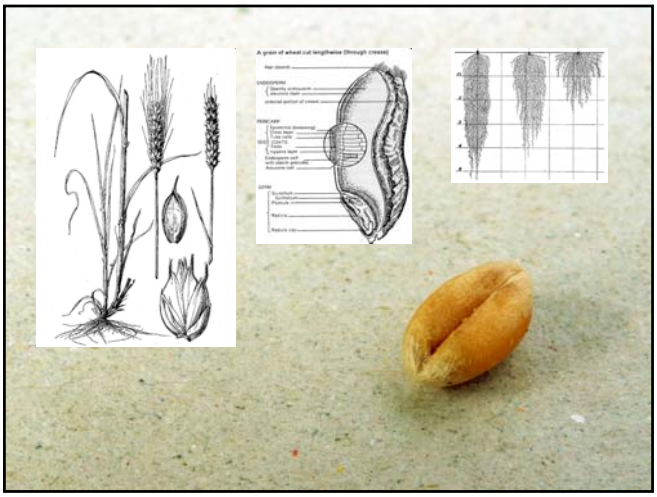
THE ROLE OF ENGINEERS



- **Engineering** : Application of science for the control and use of power especially by means of machines
- **Engineer** : Skilful or artful contriver; one who has charge of an engine
- **Engine** : Mechanical contrivance consisting of several parts working together, especially as a source of power

SPECIFICATION....

- Self-organising system
- Driven by solar energy capture
- Delivery of energy to soil biota via distributed networks embedded in the soil across multiple spatio-temporal scales
- Inherent soil structural conditioning capacity via physical reinforcement and stabilisation mechanisms
- Networks acquire and redistribute water and nutrients from deeper soil zones to upper regions
- Improve cognitive functions





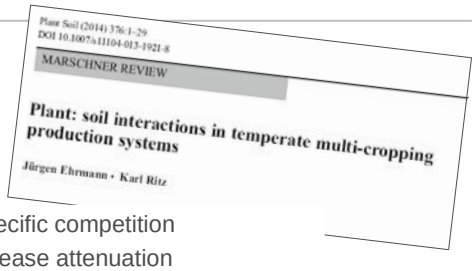
SEEDS FOR THOUGHT...

- **MONOCULTURE**
  - populations
  - very productive
  - limited ancillary functions
  - high management requirement
  - high input requirement
  - "convenient"
    - conceptually
    - management
    - to the supply chain
  - low inherent resilience
- **POLYCULTURE**
  - communities
  - very (very) productive
  - range of ancillary functions
  - high management requirement (?)
  - high input requirement (?)
  - "inconvenient" (?)
    - conceptually
    - management
    - to the supply chain
  - high inherent resilience

MULTI-CROPPING



SOILS AND BOTANICAL DIVERSITY


Plant Soil (2014) 376:1–29
DOI 10.1007/s11104-013-1921-8

MARSCHNER REVIEW

Plant: soil interactions in temperate multi-cropping production systems

Jürgen Ehrmann · Karl Ritz

- Inter-specific competition
- Pest/disease attenuation
- Community composition and structure
- Nutrient cycling
- Soil structural dynamics

(RE) – IMAGINING: POTENTIALS

- Capitalising on self-organisation
  - soil:plant system
- Role of diversity
  - spatio-temporal organisation across scales
  - intercropping / multi-cropping / polyculture
- Information acquisition and engineering
  - distributed sensor networking and environmental informatics

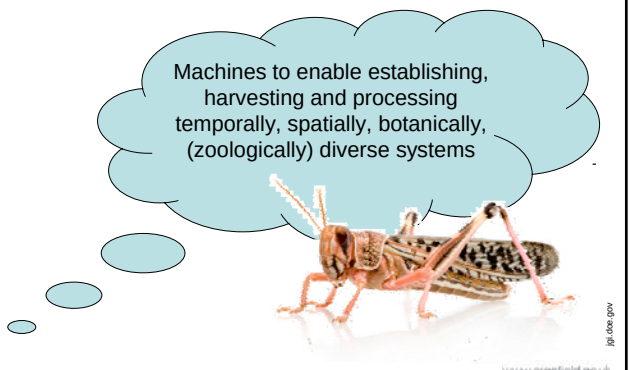
HEAVY METAL



Iron Maiden.com


Business Week

METAL AND MORE



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ECOTECHNOLOGICAL ENGINEERING

- Focus on the incipient and inherent power of ecological systems
  - soil & beyond
- Use technology to monitor, assess, inform and steer rather than substitute or subvert
- 'Hypertechnology'.... ?

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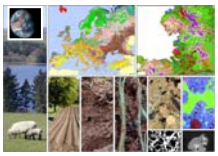
IMAGINING: THE FAR FUTURE



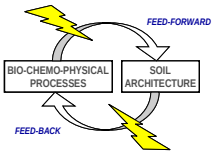
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ENGINEERING THE UNDERWORLD

DIVERT TO DIVERSITY









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